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SOIL FACTORS AND EARTHWORMS IN EASTERN ALGERIA

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Résumé

La relation entre des espèces lombriciennes de l'Est algérien et 11 facteurs du sol a été étudiée par un test de corrélation et une analyse en composantes principales (ACP).Il découle de cette étude préliminaire un dénombrement de dix-huit espèces de vers de terre dominées par des anéciques. Deux groupes peuvent être distingués : le premier constitué dans sa majorité par des endogés (*Hormogaster redii, Octodrilus maghrebinus, Octolasion lacteum, Microscolex dubius*) est lié aux teneurs élevées en matière organique. Le second est formé dans son ensemble par des anéciques (*Aporrectodea trapezoides, Allolobophora chlorotica, Aporrectodea tetramammalis, Aporrectodea carochensis*) et des endogés (*Aporrectodea rosea, Microscolex phosphoreus, Aporrectodea caliginosa, Proctodrilus antipae*), il est reliée aux milieux moins riches en sable et limon mais avec des valeurs élevées en pH et CaCO3.

***Mots clés :** Vers de terre – Biodiversité – Fertilité des sols*

Abstract

The relationships between the earthworm's species of Eastern Algeria and 11 soil characteristics have been investigated by test of correlation and analysis principal component (ACP).Eighteen earthworm species are identified in this preliminary study, dominated by the anecic species. Two groups emerge: the first consisted in its majority of endogeic species (*Hormogaster redii, Octodrilus maghrebinus, Octolasion lacteum, Microscolex dubius*) is linked to a high values of organic matter. The second is formed as a whole by the anecics (*Aporrectodea trapezoides, Allolobophora chlorotica, Aporrectodea tetramammalis, Aporrectodea carochensis*) and endogeics (*Aporrectodea rosea, Microscolex phosphoreus, Aporrectodea caliginosa, Proctodrilus antipae*), it is associated with environments less rich in sand and silt but with high values in pH and $CaCO_3$.

***Keywords :** earthworms – Biodiversity – Soil Fertility*

ملخص

تكشف هذه الدراسة عن العلاقة بين أنواع من ديدان الأرض و 11 عاملا للتربة بشرق الجزائر تبعا لمحور شمال – جنوب، بدءا من الشاطئ نحو الصحراء. لهذا الغرض استعملنا اختبارمعامل الارتباط و تحليل البيانات بواسطة الـ ACP.أدلى هذا العمل الأولي إلى إحصاء 18 نوعا من ديدان الأرض يسودها الأنواع المحبة لأعماق التربة و تمييز مجموعتين من الديدان: الأولى مكونة في مجملها من أنواع محبة للعمق الكبير (*Hormogaster redii*، *Octodrilus maghrebinus*، *Octolasion lacteum*، *Microscolex dubius*) مرتبطة بمحتويات عالية من المادة العضوية في التربة. أما الثانية فتتكون من أنواع محبة للعمق الكبير (*Aporrectodea trapezoides*، *Allolobophora chlorotica*، *Aporrectodea tetramammalis*، *Aporrectodea carochensis*) و أنواع محبة للعمق الصغير (*Aporrectodea rosea*، *Microscolex phosphoreus*، *Aporrectodea caliginosa*، *Proctodrilus antipae*) و هي مرتبطة بأوساط تفتقر لمكوني الرمل و السلت لكن قيم الـ pH و $CaCO_3$ فهي عالية.

***الكلمات المفتاحية :** ديدان الأرض –التنوع البيولوجي – خصوبة التربة*

The earthworms of North Africa are not well known. Studies about this group of soil fauna in Algeria are very limited. In the literature, we find only data on the ecological and biogeographic characteristics, particularly in Algiers area, the Kabylie and the whole of Maghreb where it was inventoried 33 species including *Criodrilus lacuum*, *Allolobophoridella eiseni*, *E. parva*, *Proctodrilus antipai*, *Dendrobaena byblica*, and *Dendrobaena lusitana*.It was added three new species (*Octodrilus maghrebinus*, *Octodrilus kabylianus* and *Eisenia xylophila*) to science from 83 localities spread over Tunisia, Algeria and Morocco [1]. The research in the area of Mitidja (a coastal plain at the south of Algiers) shows 11 species already identified [2] that*Allolobophora chlorotica* was new to North Africa, and *Prosellodrilus doumandjii* had been described as new species [3].

The researches in the Moroccan Rifand the suburbs of Constantine [4] have resulted in the presence of earthworms with Franco-Iberian affinities as *Helodrilus rifensis*[5]. Other species were also identified as *Allolobophoridella eiseni* and *Eisenia xylophila*; living in decomposed litter of *Quercus suber*. *Octodrilus complanatus*which is present in pastures, meadows and scattered trees. *Octodrilus maghrebinus* was found only in oak forests. *Dendrobaena Lusitana*, *Dendrobaena byblica* and *Dendrodrilus rubidus* were observed in the litter. The set of the Maghreb earthworms are part of the Mediterranean territory enriched by the Ethiopian element [6]. Some species of Iberian origin were observed in Morocco (*Allolobophora moebii*, *A. molleri*, *A. borellii*). While in Algeria and Tunisia it was observed species from Tyrrhenian distribution (*Hormogaster redii* and *Helodrilus festai*) with other from circum-mediterranean and centroeuropean [6]. Ouahrani and Gheribi,add a new taxon to the list of earthworms in Algeria [7].

However, no studies have been performed tothe eastern Algeria nor to a transect from the North (coast) to the South (gateway to the desert).On the one hand the identification and classification of these organisms remain difficult through lack of skilled taxonomists [8],and on the other hand the study of earthworms is not obvious to achieve due to several constraints relating to the nature of the soils and the complexity of these living organisms [9].Thus, it would be wise to look at the biodiversity earthworms of North Africa taking account climatic conditions and other phylogenetic relationships with the earthworms of Mediterranean Europe.

Based on these arguments, we have created a work team whose mission is to collect, identify and classify earthworms from Eastern Algeria. Initially the team will prepare a document faunistic and biogeographical on earthworms which will be followed by ongoing projects concerning ecological, evolutionary and phylogenetic aspects of earthworms. The interest of this teamwork is based on a consistent sampling effort as well as the taxonomic expertise qualified for the determination of earthworms.

The objective of our study is different from all the work cited above (it is the only that provides data related on biodiversity of earthworms in Eastern Algeria. It will contribute to enrich the information about the relationship of earthworms with some physical and chemical soil caracteristics. It is possible that climatic factors (temperature and precipitation) associated with soil conditions influence the earthworm's communities [9]. He suggests that the soil fauna responds to altitudinal, latitudinal or zonal gradients the same as the other living organisms.

MATERIALS AND METHODS

Thirty eight sites were sampled in Eastern Algeria (Fig. 1)throughout a North South direction from the coast to the desert. Sampling was conducted over two years (2010 and 2011), usually in the months of December and January where soils are humid and worms are active.

The coordinates of sampling stations, data and results are summarized in the Appendix 1. In our analysis, for reasons linked to the lack of data on soil parameters, we have retained only 38 stations.

Earthwoms and soil of each the 38 sites were extracted manually to a depth of 25 cm [10]. All specimens were fixed in formol at 4% or in ethanol at 96% until identified, using the external morphology of sexually mature earthworms for identification, according to keys and the specific work of Northern Africa[10, 11]. Species identificationwas carried outat the Laboratory ofSoilZoologyin Madridby Professor Dario J. Díaz Cosín.

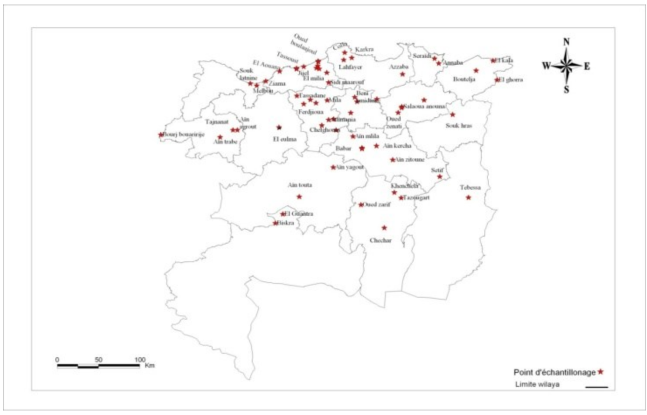

Figure1: Location of study area and sampling stations

Parameters measured

In the laboratory, we estimated biomass/m^2 and density/m^2 of earthworms. Eleven soil characteristics were determined: pH, total calcium carbonate ($CaCO_3$), calcaire actif (Ca^{++}), electrical conductivity (Ce), organic matter

(MO), organic carbon (C), total nitrogen (N), the C/N ratio and texture(sand (S), loam (L) and clay (A)).

Analysis of the data

For interpreting our results, the data obtained are analyzed using correlation tests and analysis principal component (ACP) already used to evaluate the behavior of a few species of the genus *Allolobophora*[12]and to determine the populations of earthworms according to the vegetation types [13].

RESULTS

Eighteen species were identified (table 1). The species *Ap. trapezoides*is most dominant in the study area.The anecic earthworms are the most frequent. They are able to nest in the deeper layers where they can probably develop mechanisms of resistance such as estivation or other.

Soil characteristics and earthworms interactions

Table 2 indicates that the pH is negatively and moderately correlated with density (r = - 0,43). However, the conductivity is negatively correlated with density (r = - 0,41) and biomass (r = - 0,49).

It seems that conductivity impedes the activity of the earthworms. With regard to the influence of pH, the situation is more linked to climatic factors; because the density of earthworms is low at the sitesat high pH,located in semi arid and arid area. Unlike the stations at low pH, located in the humid and sub-humid bioclimatic stages which reveal a higher density; certainly the humidity is the limiting factor.The ACP analysis exposes the following results.

Table 1: List of the earthworm species collected in Eastern Algeria.

Family	Species	Ecological categories	Frequency	Type of habitat
Lumbricidae	*1)Aporrectodea trapezoides* (Dugès, 1828)	Anecic	42	Prairies, the oak forests, fields and greenhouses of culture
	2) Aporrectodea rosea (Savigny, 1826)	Endogeic	25	Prairies, the oak forests, fields and greenhouses of culture, palm groves.
	3) Allolobophora molleri (Rosa, 1889)	Endogeic	15	The prairies, and swampy areas
	4) Aporrectodea montícola (Pérez Onteniente & Rodríguez Babio, 2002*)*	Endogeic	2	Crop fields
	5) Octodrilus complanatus (Dugès, 1828)	Anecic	4	The prairies, andareas, rich in plant debris
	6) Aporrectodea carochensis (Pérez Onteniente &Rodriguez Babio, 2002)	Anecic	1	The prairies
	7) Octodrilus maghrebinus, Omodeo & Martinucci, 1987	Endogeic	2	Oak forest
	8) Eisenia foetida (Savigny, 1826)	Epigeic	1	Area rich in organic debris
	9) Dendrobaena byblica, Rosa,1893	Epigeic	1	Oak Forest
	10) Aporrectodea tetramammalis (Pérez Onteniente &Rodriguez Babio, 2002)	Anecic	2	Wet prairie
	11) Eiseniella tetraedra (Savigny, 1826)	Epigeic	1	Olive grove
	12) Proctodrilus antipae (Michaelsen, 1891)	Endogeic	1	Prairies
	13) Octolasion lacteum (Örley, 1881)	Endogeic	1	Wet prairie
	14) Aporrectodea caliginosa (Savigny, 1826)	Endogeic	1	Olive grove
	15) Allolobophora chlorotica (Savigny, 1826)	Anecic	1	fields and greenhouses of culture
Megascoleidae ascolecidae	*16) Microscolex dubius* (Fletcher, 1887)	Endogeic	3	Prairies
	17) Microscolex phosphoreus (Dugès, 1837)	Endogeic	3	Prairies
Hormog astridae	*18) Hormogaster redii, Rosa, 1887*	Endogeic	1	Oak forest (Dj. Edough)

Table 2 : Correlations between the earthworms and soil parameters

	Density	Biomass
pH	-0,43	-0,18
Con	-0,41	-0,49
$CaCO^3$	-0,28	-0,25
Ca++	-0,16	0,01
C%	0,38	0,08
N%	0,03	0,10
C/N	0,05	-0,19
M.O%	-0,07	-0,09
S	-0,29	-0,26
A	0,12	0,08
L	0,34	0,34

Fig 2 shows thatthe plan (1,2) provides 44.60% of total information, What is moderately acceptable. The test of the correlations between variables shows that the density (r = 0,69), carbon (r = 0,59), biomass (r = 0,54)and partially organic matter (r = 0.41) contribute to the formation of the positive side of the factorial axis F1, however pH, $CaCO_3$ and electrical conductivity develop its negative side.

The F2 axis opposed the sandy fraction (r = 0.68) and C/N ratio (r = 0.46) to the variables calcaire actif, loam, density and biomass.In the plan (1,3), the total information is of 42.62%. The F3 Axis opposed the fraction clay (r = 0.70) and organic matter (r = 0.57) to the sandy fraction and Nitrogen total (fig.3).

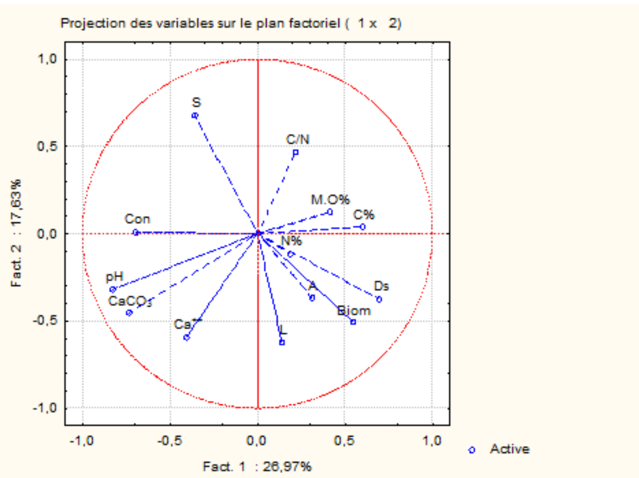

Fig. 2: ACP of soil parametersand earthworms in the plan 1x2

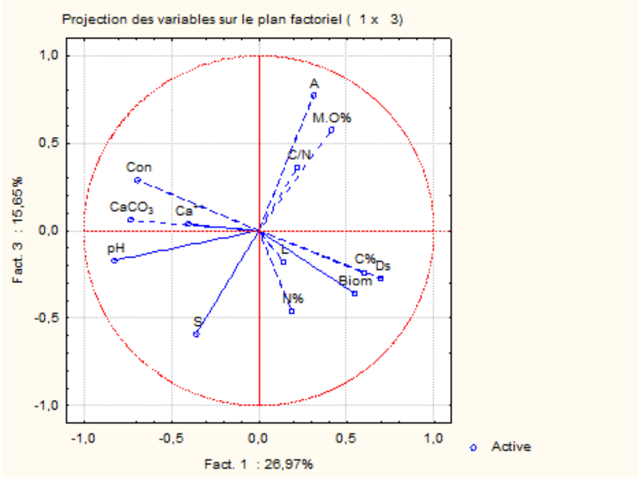

Fig. 3:ACP of soil parameters and earthworms in the plan 1x3

The projection of sampling sites on the map (1,2) shows that stations: Eg, Bb, Lh, Blg, Ok, Ans, An, Ozr, Oh, Obo, Kr and Sr (quadrant1) are characterized by a soil rich in organic matter and carbon.The stations Aok, Di, Ts, Em and Sm (quadrant 2) are influenced by the loam and clay. Here, earthworm's density and biomass are high. Points Fr, Am, Rc, Ath, Ml and Tsd (quadrant3) are related to the edaphic parameters $CaCO_3$, Ca^{++} and pH. However, Tb, Gun, Adk, Bab, Bsk, Taz, Rj, Kh, Azt and SO (quadrant4) are distinguished by the sandy fraction, and also the conductivity especially for Azt (fig.4).

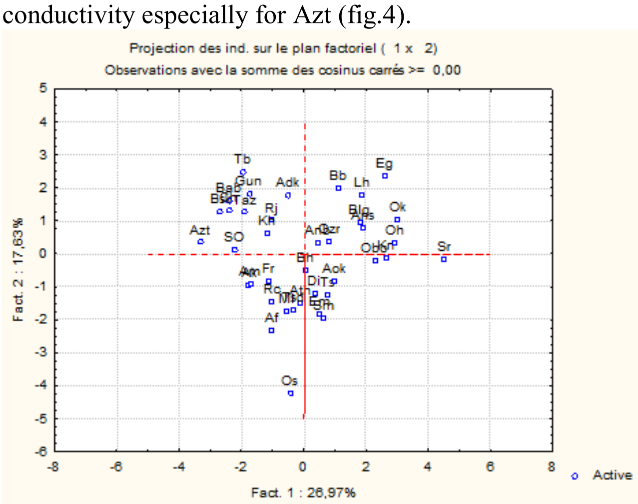

Fig. 4: The interaction of soil factors and sampling stations, according to the projection 1 x 2

According to figure 5, the projection of the stations on the plan (1.3) shows that the soils of Ans, Lh, Kn, Obo, Ts, Aok, Ok, Di (quadrant1) are rich in clay and organic matter mainly in Eg. However the stations Ozr, Bb, blg, Oh, Em, Sm, Anb et Sr (quadrant2) are defined by the carbon, nitrogen as well as the strong values of density and biomass of earthworms.

Points Ch, Bab, Kh, Rj, Ts, Ath, Tsd and Tb (quadrant3) seem to be influenced by the sandy fraction and the variable pH. While the soils of the stations: Ak, Azt, Bsk, Am, Af, Gun, So, Taz, Rc, Bh, Fr, Adk, Ml and OS (quadrant 4)are characterized by the parameters $CaCO_3$, Ca^{++} and conductivity.

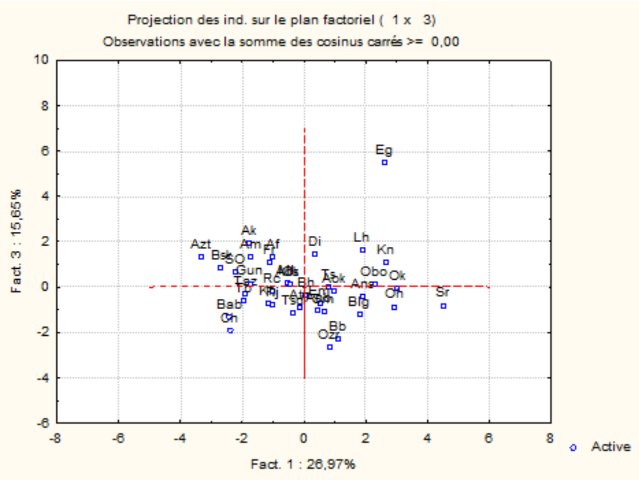

Fig. 5: The interaction of soil factors and sampling stations according to the projection 1 x 3

Interactions between earthworm's species and soil factors

The analysis principal component (ACP) leads to the selection of the section, representing 62.37% of the total variability data. The correlation between distributions is rises to 37.86% for axis F1 and 24.51% for F2 (fig. 6).

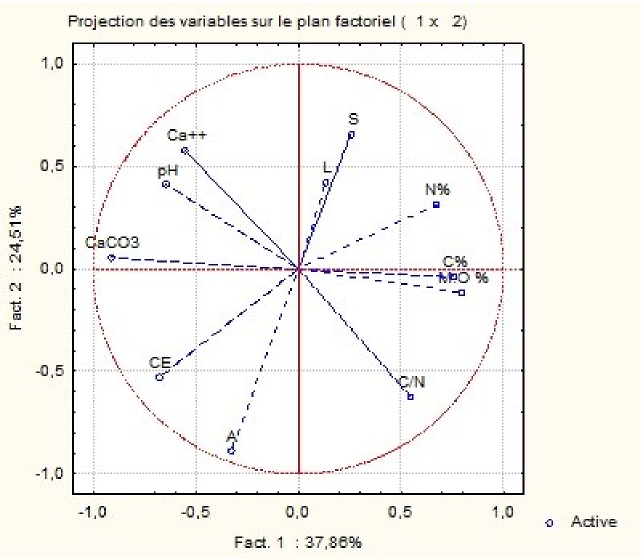

Fig. 6: ACP of soil parameters and earthworms species in the plan 1x3

The F1 axis opposed variables M.O (r = 0.79), C% (r = 0.75), N% (r = 0.67) and C/N (r = 0.54)to soil factors pH, Ca CO_3, Ce and Ca^{++}.

However the F2 axis is explained by the parameters: sandy (r = 0.65), Ca^{++} (r= 0.57) and moderately by loam, pH (r =0.41) and N (0.31) which contribute to the formation of its positive side. All these information are opposed to the variables of clay, C/N ratio and electrical conductivity located on the negative side.

The projection of the biodiversity of the earthworms and soil factors (fig. 7) indicates that the taxa*Dendrobaena byblica, Octodrilus complanatus and Allolobophora molleri* (quadrant1)form a group associated with soilfactors: sand, loam, and nitrogen. The Species: *Hormogaster redii, Octodrilus maghrebinus, Octolasion lacteum, Microscolex dubius* (quadrant2), have the same soil requirements attached mainly to organic matter, carbon and the C/N ratio.However, the species *Allolobophora chlorotica, Aporrectodea tetramammalis, Aporrectodea rosea* and surtout *Aporrectodea carochensis* (quadrant3), are influenced by the clay fraction and the conductivity. However the species:*Aporrectodea trapezoides, Aporrectodea montícola, Eiseniella tetraedra, Microscolex phosphoreus, Proctodrilus antipae, Aporrectodea caliginosa, and Eisenia foetida* (quadrant4), appear to be influenced by $CaCO_3$, Ca^{++} and pH.

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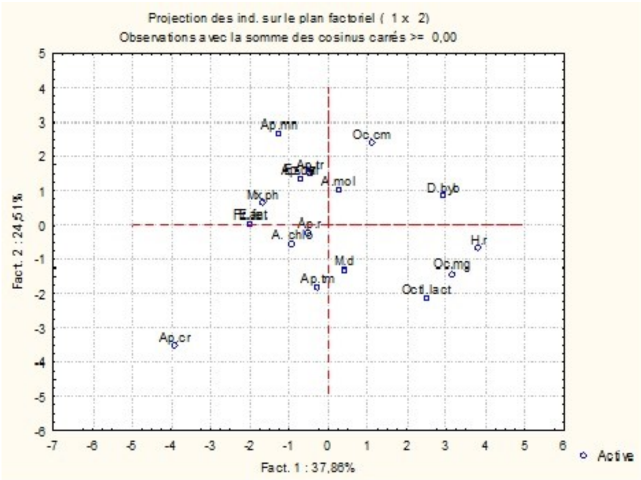

Fig. 7: The interaction of soil factors and earthworms species according to the projection 1x3

DISCUSSION

In Algeria, the transition of the northern part well watered to the southern sector arid and poor, is fast and you get faster to the steppe area [14].

The climate,usually dry, is not favourable to the development and dispersal of earthworms.The reason why, earthworm's biodiversity is low throughout the Maghreb territory (Morocco, Algeria and Tunisia);where 33 specieshave been determined of which 24 are located in Algeria [6]. In the studied transect we have identified 18 species, of which 10 had been already determined [6]. In the Algiers region11 species had been identified [2]. Also, 11 species were found in the Constantine area [15]. In our case, 4 species do not appear in the list of these authors: *Ap. trapezoides, Ap. monticola*, *Ap. tetramammalis* et *Ap. carochensis.*

In General, Eastern Algeria earthworms dominated by species *Ap. trapezoides*,are a smaller version of the southern iberian peninsula fauna, especially the South of Andalusia and the Portugal with some endemic forms, and a few circum-mediterranean and tyrrhenian species such as *H. redii*[16], [17] and [18].The presence of the latter in Algeria and Tunisia reveals the existence of a relationship between the Corsica-Sardinia-Sicily-Italy and the North African[6] and [19].

Extending from the wet stage bioclimatic on the arid, our field of study covers a diversity of soils, which is explained by the nature of the bedrock responsible for the formation of acidic substrates on the northern part of the country and more calcareous soil inwards the southern area.

There is also the precipitation'sparameter which play a role in soil leaching, leading to pH with mean values ranging from 6,96 ± 0,84 in the humid bioclimatic stage (to the North) to 8,09 ± 0,37 and 8.00 ± 0,31 in the sub-arid and arid (to the South). The average values of CaCO3 oscillate from 13.65 ± 19.33 in the wet bioclimatic stage at 39.21 ± 19.95 and 60.71 23.93 respectively in the arid and semi arid. The conductivity values are considerably less than 8 ms/cm, so the soil is not saline. However, the values are higher in inland stations in the semi arid and arid stages due to the presence of rocks rich in limestone or gypsum [20].The reason why the soils are highly to excessively calcareous in sampling stations of this part of our study field.

All these factors may influence biological diversity, distribution and abundance of the earthworm's populations. The works[21] and [22] define values limits of pH with the distribution of earthworms which are generally absent in very acidic soils (pH <3.5) and few in soils with a pH < 4.5 [23].The majority of species of temperate regions are found in soils with pH between 5.0 and 7.4 [24].In our study, the low values of density and biomass are located in the sampling stations where the averages of pH, $CaCO_3$ and conductivity are high,but they are also, due to aridity characterizing these environments.

Other factors may influence the distribution and abundance of earthworm's populations, as the type and texture of the soil [25], [26] and [27]. Furthermore,it was found a significant positive correlation between the abundance of earthworms and the rate of clay soils [28]. In our work, lumbricidae parameters (density and biomass) are also related to the silty and clayey fraction while emphasizing that the stations containing more clay are consistent to the elevated M.O.

The assessment of the level of organic matter is based on the content of clay and calcaire soil. More soil is calcareous, more it blocks organics matter. For soils of our stations located on bioclimatic semi arid and arid stages are weak to moderately equipped in M.O, While those in the northern part of the transect (sub humid and humid), the levels are well equipped to high, they are between 6.00 ± 1.80 and 5.80 ± 9.75. Here, the density of the lumbricidae is higher; that suggests a close link of earthworms with the M.O, which is the source of their food. Many studies have shown a positive correlation between the density or biomass of earthworms and the content of organic matter in the soil [29], [30].

In this study, the parameters C, M.O, N, clay and silt are correlated. They still oppose the sandy texture. In general, heavy soils contain more total nitrogen than the light soil[31].

Our sampling soils are generally rich in nitrogen,particularly northern stations where averages are identified in the order of 0.73 ± 0.47 (humid stage) to 1.06 ± 0.37 (sub humid stage). These levels can be explained by the texture of soils and their high clay content[31], as well as the rate of the M.O which play an important role in the supply of nitrogen soil after its mineralization [31].

The C/N ratio provides useful indications on the evolution of the organic matter of the soil. The values are weak overall statements of our stations (averages range from 2.98 ± 1.41 to 5.38 ± 3.80)that show that theconditions are favorable for the high mineralization of organic matter signifying a good biological activity.

So, the edaphic parameters affect the earthworm's species. There is an optimal pH for each species [26].Alsothey have food preferences;it was shown that most worms prefer the manure or fat herbs and the leaves of the trees [32]. However, the pine needles were less appreciated.

The C/N ratio is a measure of quality of the organic material as a source of energy. It was awarded 49 species for which the C/N ratio optimal for growth is less than 13 and 18 species have an optimal C/N greater than or equal to this value [10]. It was reported that*Aporrectodea caliginosa, Aporrectodea rosea, Lumbricus terrestris* and *Lumbricus castaneus*occupy the soil with a C/N ratio less than 8 [33]. It is also the case for soils and earthworms in our field of study.

The results obtained in this study allow defining two groups of species. The first consist in its majority ofendogeic species(*Hormogaster redii, Octodrilus maghrebinus, Octolasion lacteum, Microscolex* *dubius*),presents trends toward soils with high organic matter content, sandy and silty fractions but less rich in clay. The second group formed as a whole by anecics (*Aporrectodea trapezoides, Allolobophora chlorotica, Aporrectodea tetramammalis, Aporrectodea carochensis*) and endogeic species (*Aporrectodea rosea, Microscolex phosphoreus, Aporrectodea caliginosa, Proctodrilus antipae*) shows a trend with low values of sand and silt but high values for pH and $CaCO_3$.

These results approach the different works cited in the literature.*Octodrilus maghrebinus* is a species more associated with oak forests [6].*Octolasion lacteum*has been described as taxon confined in biotopes organic, neutrophils and relatively acidtolerant [10]. *Hormogaster redii,* seems fond relatively damp places and pH flanking 6.2 [10]. It is also harvested in the forest of Edough (Algeria)[6],it is rumored as a species of litter and remains limited in oak forest-covered mountain[1].*Microscolex dubius*is neutrophils and relatively acidotolerante and linked to humid soils clay or sandy rich in litter[10]. The *Octodrilus complanatus* taxon is present in agricultural soils and the edges of forests mainly in the areas of sparse trees and wet organic substrates [34].

The species of the second group are more affected by other soil factors. *Allolobophora chlorotica* which is a ripicol species, hygrophile, affecting wetlands; it presents characters of calcareous and lives in less organic substrate[10].*P.antipai*is subservient to the floodplains;it prefers essentially alluvial type clay soils [35].*Ap. Caliginosa* may be present in all types of substrate even in poor sand soil [38] and [39]. *Aporrectodea rosea* is indifferent to the type of substrate, it is generally more abundant in moist soils, and itnests in the mineral horizon[1]. *Aporrectodea trapezoides*is often abundant in the orchards and fields of crops receiving important inputs of organic matter [38]. *Allolobophora molleri* lives in very wet soils with a pH from 5.75 to 7.0[39]. With regard to *Eisenia foetida*, which meets only in organic-rich environmentssuch as animal manure or compost piles, it lives in the upper mineral soil horizon [26].

In this regard, many deviations are found between different authors for example some factorsseem important for a species may be not significant for the other [40, 41, 42]. These divergences between authors can be explained by the use of numerical methods which some would be inappropriate for the desired objectives [43].

It should be noted also that the soil is a complex environment where the interaction between several factors, such as the bedrock, the climate, the topography and the vegetation,is non-negligible. All these parameters influence the dynamics of populations of earthworms.

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Appendix 1: Coordinates and elevation of the sampling stations.

N°	Station	Code	Altitude (m)	Latitude N	Longitude E	2010	2011
1	Jijel	Ji	17	36°48'05.22''	005°51'42.90''		X
2	Tassoust	Ts	23	36°48'36.70''	005°51'42.90''	X	X
3	El kannar	Kn	16	36°49'36.71''	005°57'16.13''	X	X
4	Beni belaïd	Bb	8	36°53'27.11''	006°08'39.17''	X	X
5	Oued Kebir	Ok	97	36°50'08.97''	006°08'19.35''		X
6	Belghimouz	Blg	47	36°48'47.81''	006°07'10.81''		X
7	Oued boulaajoul	Obo	42	36°52'56.05''	006°08'37.72''	X	X
8	El Ansar	Ans	12	36°48'11.81''	006°09'27.74''	X	X
9	El milia	Em	106	36°45'41.06''	006°15'27.10''	X	X
10	Sidi maarouf	Sm	71	36°39'09.93''	006°16'50.44''	X	X
11	Mila	Ml	426	36°27'22.03''	006°15'47.40''	X	X
12	Tassadane	Tsd	581	36°30'18.69''	005°52'01.40''		X
13	Redjas	Rj	346	36°25'28.88''	006°06'59.56''	X	X
14	Rouached	Rc	517	36°27'42.18''	006°02'29.51''	X	X
15	Ferdjioua	Fr	571	36°24'53.11''	005°57'23.42''		X
16	Athmania	Ath	757	36°14'21.97''	006°16'50.62''	X	X
17	Beni hmidane	Bh	517	36°29'21.72''	006°37'12.99''		X
18	Chelghoum	Chg	749	36°10'40.16''	006°11'32.88''		X
19	Didouche	Di	745	36°26'28.64''	006°38'59.12''		X
20	Oued seguane	Os	783	36 14' 54.0''	006° 20' 49.2''	X	X
21	Constantine	Cn	819	36°18'54.58''	006°34'12.61''		X
22	Azzaba	Az	38	36°44'39.2''	007°14'45.5''		X
23	Collo	Co	587	36°59'03.23''	006°29'27.55''		X

Appendix 1 bis: Coordinates and elevation of the sampling stations.

N°	Station	Code	Altitude (m)	Latitude N	Longitude E	2010	2011
24	Karkra	Kr	25	36°55’34.60’’	006°35’00.37’’		X
25	Ouledhbaba	Oh	722	36°28’06.19’’	006°54’40.71’’		X
26	Lahfayer	Lh	135	36°54’06.34’’	006°28’42.62’’		X
27	Annaba	An	4	36°51’52.3’’	007°43’03.2’’		X
28	Seraïdi	Sr	729	36°55’05.58’’	007°39’47.60’’		X
29	Boutelja	Bt	28	36°47’06.3’’	008°12’20.4’’		X
30	El kala	Ek	76	36°53’36.9’’	008°25’32.32’’		X
31	El ghorra	Eg	734	36°40’52.36’’	008°28’35.97’’		X
32	Oued zenati	Ozn	669	36°19’006’’	007°11’13.2’’		X
33	Guelma	Gu	177	36°27’28.7’’	007°31’30.7’’		X
34	Aïnfakroune	Af	1031	35°56’57.54’’	006°54’21.33’’	X	X
35	Aïnkercha	Ak	831	35°55’45.95’’	006°42’56.36’’	X	X
36	Aïnmlila	Am	763	36°03’16.26’’	006°35’51.88’’	X	X
37	Aïnzitoune	Azt	850	35°47’43.02’’	007°06’57.97’’	X	X
38	Tazougart	Taz	1114	35°22’29.54’’	007°13’33.43’’		X
39	Babar	Bab	1065	35°55’05.58’’	006°42’56.36’’		X
40	Tebessa	Tb	994	35°22’44.59’’	008°06’18.62’’	X	X
41	Telaghma	TL	735	36°07’36,01’’	006°22’43.20’’		X
42	Khenchela	Kh	1162	35°25’59.35’’N	007°08’17.14’’E	X	X
43	Oued zarif	Ozr	1239	35°17450.64’N	006°42’12.51’’E	X	
44	Chechar	Ch	1153	35°02’34.33’’N	007°00’28.67’’E	X	X
45	El Guantra	Gun	476	35°11’38.0’’	005°40’59.3’’		X
46	Biskra	Bsk	321	35°05’36.8’’	005°35’10.1’’	X	X